MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 3, 2016/2017

EEE3106 – PROCESSING AND FABRICATION TECHNOLOGY

(EE)

31 MAY 2017
2.30 p.m - 4.30 p.m
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 7 pages with 4 Questions only.
2. Attempt **ALL** questions. The distribution of the marks for each question is given.
3. Please print all your answers in the Answer Booklet provided.
4. Please refer to the APPENDIX section on pages 6 and 7 for a list of physical constants, formulas, and the error function table.

Question 1

(a) Why is silicon (Si) preferred over germanium for the fabrication of semiconductor devices in microelectronic industries? [6 marks]

(b) After the crystal growth process, the silicon ingot needs to be processed further into thin wafers before these wafers can be used for device fabrication. Briefly describe these processing steps. [9 marks]

(c) A boule of single crystal Si is pulled from the melt which is contained in a crucible of a Czochralski crystal puller. The dopant is boron, which is in solid form. After the Si boule is pulled, it is sliced into thin sheet of wafers. The wafer taken from the top of the Si boule has a doping concentration of 1×10^{16} cm^{-3}.The segregation coefficient (k) for boron is given as 0.8. Determine the doping concentration of the wafer taken from the position corresponding to 85% of the initial charge solidified. [5 marks]

Continued .....

Question 2

Fig.Q2 depicts the schematic cross-section of a micron-sized p-type zinc oxide/n-type silicon (p-ZnO/n-Si) heterojunction photodiode. The photodiode consists of p-ZnO deposited on n-type silicon substrate, with nickel/gold (Ni/Au) alloy and aluminum (Al) serving as the front and back photodiode electrodes, respectively.

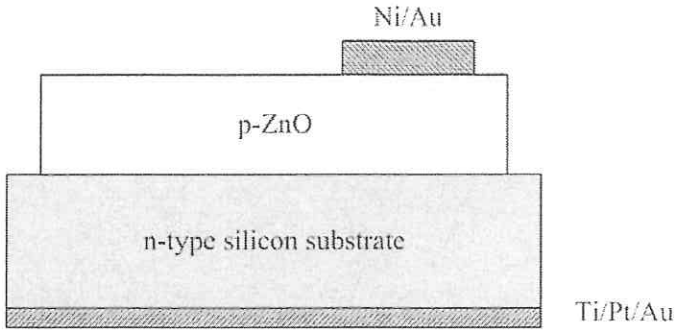

Fig. Q2: Schematic cross-section of a p-ZnO/n-Si heterojunction photodiode.

(a) Design a fabrication process flow for the p-ZnO/n-Si heterojunction photodiode depicted in **Fig.Q2**. With neat sketches, describe your design processing flow. How many masks are required in the patterning of the photodiode? [13+1 marks]

(b) Photolithography is the technology of choice for patterning the photodiode with device feature size in the range of micrometer.

(i) If the contamination on the substrate and optical mask can be tolerated in the photolithography process, but the resolution of the photolithography process is a priority, which type of the photolithography technique is preferred in the fabrication of the photodiode? Justify your selection. [4 marks]

(ii) A mask aligner system uses an *i*-line source with wavelength of 365 nm. If the photoresist thickness is 1 μm and photoresist constant is, k = 0.8, determine the minimum feature size, W_{min}, that can be achieved by using a hard contact mask aligner, and a mask aligner with an air gap of 30 μm, respectively. [4 marks]

(c) Suggest a physical vapour deposition technique to deposit Ni/Au alloy and Al metal which serve as the photodiode electrodes in **Fig. Q2**. Discuss the advantages and the operational principle for the suggested deposition technique. [8 marks]

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Question 3

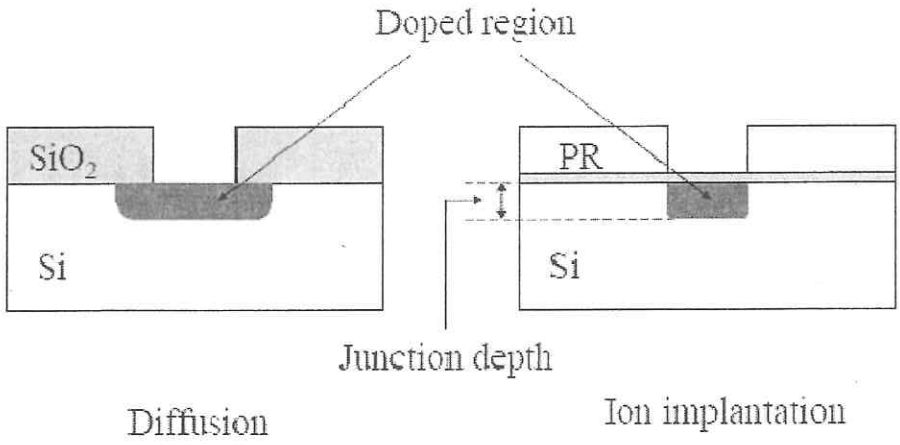

Fig Q3(a): Doping profiles obtained from diffusion and ion implantation processes.

(a) **Fig. Q3(a)** depicts the different doping profiles obtained from the diffusion and ion implantation processes. SiO_2 and PR are the silicon dioxide and photoresist layers, respectively. Based on **Fig. Q3(a)**, discuss TWO (2) disadvantages of the diffusion process and TWO (2) advantages of the ion implantation process.

[4 marks]

(b) A p-type Si wafer with a background concentration of 10^{16}cm^{-3} is doped with arsenic (As) ions using the drive-in diffusion process at a temperature of 1000°C for 30 minutes. At the end of the doping process, the As dopant concentration at the surface of the wafer is 10^{19}cm^{-3}. It is given that the diffusivity of As in Si is $1.6 \times 10^{-15} \frac{\text{cm}^2}{\text{s}}$ at 1000 °C.

(i) What is the primary objective of the diffusion process described above?

[1 mark]

(ii) Determine the dose of the As atoms for the diffusion process, in cm^{-2}.

[2 marks]

(iii) Calculate the junction depth. [3 marks]

(c) List down THREE (3) interconnect materials and identify their specific uses.

[6 marks]

(d) Highlight the importance of obtaining highly planar layers of metallization on a semiconductor surface. Briefly describe the process of planarizing the metallization layers, as shown in **Fig. Q3(d)**. [4 marks]

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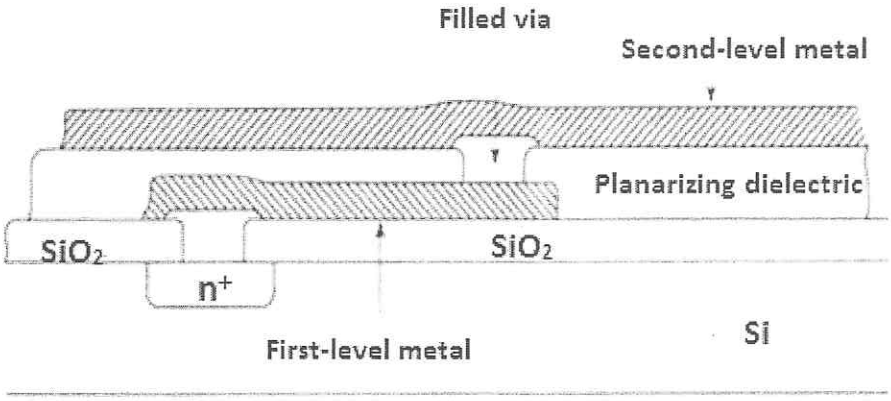

Fig. Q3(d): Planarized metallization on a Si substrate.

Question 4

(a) Packaging is the final step involved after the wafer fabrication process. Briefly explain the FOUR (4) purposes of packaging. [4 marks]

(b) What is the purpose of wire bonding the die to the package after the die attachment process? Describe how ultrasonic bonding is carried out. [1 + 8 marks]

(c) As a semiconductor packaging engineer, suggest ONE (1) suitable type of package for EACH of the following requirements:

(i) Able to be used over a wide temperature range
(ii) Has high pin density
(iii) Able to be mounted/soldered/attached onto the printed circuit boards (PCBs) without requiring through-holes [6 marks]

(d) As a manufacturer, you are interested to know the yield of the dice produced. Explain TWO (2) importances of determining the yield. [4 marks]

(e) A 300 mm wafer has a defect density of 50 defects/cm^2. Each die on the wafer has a size of 4 × 4 mm^2. Assuming uniform defect density, determine the minimum market price for each die if the cost for testing and packaging each die is RM 2.00, while the total fabrication cost is RM 600. Suggest ONE (1) way to increase the yield of the dice. [7 marks]

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APPENDIX

Physical Constants:

Avogadro number, $N_{avo} = 6.02217\times10^{23}$ mol^{-1}
Boltzmann constant, $k = 1.380622\times10^{-23}$ J K^{-1} = 8.61712×10^{-5} eV K^{-1}
Electronic charge, $e = 1.60219\times10^{-19}$ C
Electron rest mass, $m_o = 9.10956\times10^{-31}$ kg
Electron volt, 1 eV = 1.60219×10^{-19} J
Si yield strength = 2×10^{7} dynes cm = 7 GPa
Latent heat of fusion for Si, L = 340 cal g^{-1}
Thermal conductivity of Si, k = 0.21 W cm^{-1} °C^{-1}
Amount of heat of 1 calorie = 4.14 J
Density of bulk Si = 2.33 g cm^{-3}
Density of molten Si = 2.53 g cm^{-3}
Electric current of 1 A = 1 Cs^{-1}
Atomic mass unit of 1 amu = 1.66053×10^{-27} kg
Magnetic flux density of 1 T = 1 Wb m^{-2} = 10^{4} G
Angstrom unit of 1 Å = 1×10^{-10} m = 0.1 nm = 1×10^{-4} μm
Permittivity of free space = 8.85×10^{-14} F cm^{-1}
Pressure of 1 Torr = 133.32237 Pa

Formulas:

$C = kC_O(1-x)^{k-1}$	$C_S = \dfrac{Q_T}{\sqrt{\pi Dt}}$
$\boldsymbol{\sigma = pq\mu}$	$N(x) = \dfrac{Q_O}{\sqrt{2\pi}\Delta R_P} e^{\left[\frac{-1}{2}\left(\frac{x-R_P}{\Delta R_P}\right)^2\right]}$
$\boldsymbol{W_{min} = \sqrt{k\lambda g}}$	$Y = e^{-D_O A}$
$C(x,t) = C_S\, erfc\left[\dfrac{x}{2\sqrt{Dt}}\right]$	$Y = \left[\dfrac{1-e^{-D_O A}}{D_O A}\right]^2$
$Q = 2C_S\sqrt{\dfrac{Dt}{\pi}}$	$Y = \left[\dfrac{1-e^{-2D_O A}}{2D_O A}\right]$
$C(x,t) = \dfrac{Q_T}{\sqrt{\pi Dt}} e^{-\frac{x^2}{4Dt}}$	$N = \dfrac{\pi(r-S)^2}{S^2}$

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Values of the error function $\operatorname{erf}(t) = \frac{2}{\sqrt{\pi}} \int_0^t e^{-a^2} \, da$

t	0	1	2	3	4	5	6	7	8	9
0.0	0.000	0.0113	0.0226	0.0338	0.0451	0.0564	0.0676	0.0789	0.0901	0.1013
0.1	0.1125	0.1236	0.1348	0.1459	0.1569	0.1680	0.1790	0.1900	0.2009	0.2118
0.2	0.2227	0.2335	0.2443	0.2550	0.2657	0.2763	0.2869	0.2974	0.3079	0.3183
0.3	0.3286	0.3389	0.3491	0.3593	0.3694	0.3794	0.3893	0.3992	0.4090	0.4187
0.4	0.4284	0.4380	0.4475	0.4569	0.4662	0.4755	0.4847	0.4937	0.5027	0.5117
0.5	0.5205	0.5292	0.5379	0.5465	0.5549	0.5633	0.5716	0.5798	0.5879	0.5959
0.6	0.6039	0.6117	0.6194	0.6270	0.6346	0.6420	0.6494	0.6566	0.6638	0.6708
0.7	0.6778	0.6847	0.6914	0.6981	0.7047	0.7112	0.7175	0.7238	0.7300	0.7361
0.8	0.7421	0.7480	0.7538	0.7595	0.7651	0.7707	0.7761	0.7814	0.7867	0.7918
0.9	0.7969	0.8019	0.8068	0.8116	0.8163	0.8209	0.8254	0.8299	0.8342	0.8385
1.0	0.8472	0.8468	0.8508	0.8548	0.8586	0.8624	0.8661	0.8698	0.8733	0.8768
1.1	0.8802	0.8835	0.8868	0.8900	0.8931	0.8961	0.8991	0.9020	0.9048	0.9076
1.2	0.9103	0.9130	0.9155	0.9181	0.9205	0.9229	0.9252	0.9275	0.9297	0.9319
1.3	0.9340	0.9361	0.9381	0.9400	0.9419	0.9438	0.9456	0.9473	0.9490	0.9507
1.4	0.9523	0.9539	0.9554	0.9569	0.9583	0.9597	0.9611	0.9624	0.9637	0.9649
1.5	0.9661	0.9673	0.9684	0.9695	0.9706	0.9716	0.9726	0.9736	0.9746	0.9755
1.6	0.9764	0.9772	0.9780	0.9789	0.9796	0.9804	0.9811	0.9818	0.9825	0.9832
1.7	0.9838	0.9844	0.9850	0.9856	0.9861	0.9867	0.9872	0.9877	0.9882	0.9886
1.8	0.9891	0.9895	0.9899	0.9904	0.9907	0.9911	0.9915	0.9918	0.9922	0.9925
1.9	.99279	.99309	.99338	.99366	.99392	.99418	.99443	.99466	.99489	.99511
2.0	.99532	.99552	.99572	.99591	.99609	.99626	.99642	.99658	.99673	.99688
2.1	.99702	.99715	.99728	.99741	.99753	.99764	.99775	.99785	.99795	.99805
2.2	.99814	.99822	.99831	.99839	.99846	.99854	.99861	.99867	.99874	.99880
2.3	.99886	.99891	.99897	.99902	.99906	.99911	.99915	.99920	.99924	.99928
2.4	.99931	.99935	.99938	.99941	.99944	.99947	.99950	.99952	.99955	.99957
2.5	.99959	.99961	.99963	.99965	.99967	.99969	.99971	.99972	.99974	.99975
2.6	.99976	.99978	.99979	.99980	.99981	.99982	.99983	.99984	.99985	.99986
2.7	.99987	.99987	.99988	.99989	.99989	.99990	.99991	.99991	.99992	.99992
2.8	.99992	.99993	.99993	.99994	.99994	.99994	.99995	.99995	.99995	.99996
2.9	.99996	.99996	.99996	.99997	.99997	.99997	.99997	.99997	.99997	.99998
3.0	.99998	.99998	.99998	.99998	.99998	.99998	.99998	.99999	.99999	.99999

for $t > 3$ $\quad \operatorname{erf}(t) \approx 1 - \frac{1}{\sqrt{\pi}\, t} \exp\left(-t^2\right)$

$\operatorname{erfc}(t) = 1 - \operatorname{erf}(t)$

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